CMC Research at NASA Glenn in 2013: Recent Progress and Plans

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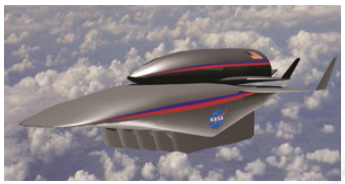
NASA Aeronautics Programs



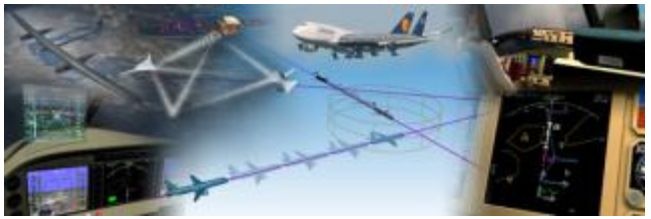
Fundamental Aeronautics Program

Conduct fundamental research that will produce innovative concepts, tools, and technologies to enable revolutionary changes for vehicles that fly in all speed regimes.

Integrated Systems Research Program

Conduct research at an integrated system-level on promising concepts and technologies and explore/assess/demonstrate the benefits in a relevant environment



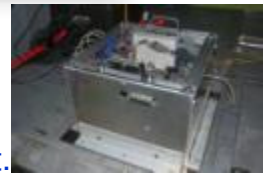


Airspace Systems Program

Directly address the fundamental ATM research needs for NextGen by developing revolutionary concepts, capabilities, and technologies that will enable significant increases in the capacity, efficiency and flexibility of the NAS.


Aviation Safety Program

Conduct cutting-edge research that will produce innovative concepts, tools, and technologies to improve the intrinsic safety attributes of current and future aircraft.




Aeronautics Test Program

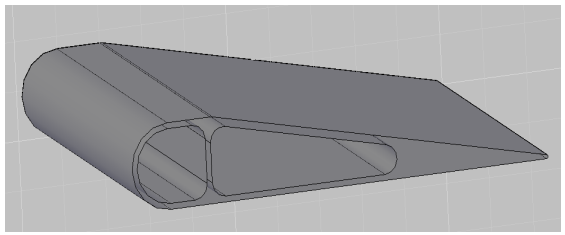
Preserve and promote the testing capabilities of one of the United States' largest, most versatile and comprehensive set of flight and ground-based research facilities.




2012 Accomplishments

- Fabricated and tested SiC/SiC turbine and combustor subelements
- Evaluated advanced Environmental Barrier Coatings in simulated engine environment
- Demonstrated oxide CMC subelements for engine noise reduction
- Developed processing approach and measured creep properties of CMCs with 2700°F hybrid CVI/PIP SiC matrix

Durability testing of turbine vane subelement in simulated turbine environment has been initiated



turbine vane subelement

EBC

- 5-10 mil thick multilayer coating with hafnia-silicon bond coat and rare earth silicate coatings
- 2700 ºF temperature capability
- Plasma Spray / PVD application process

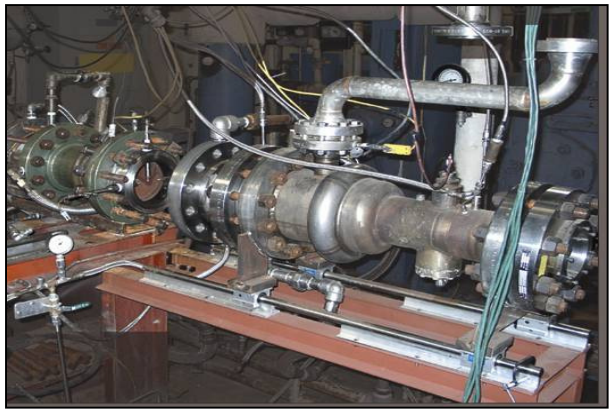
1. Prepreg MI SiC/SiC

- *Hi-Nic Type S fibers*
- *BN interface coatings*
- 0/90/0/0/90/0º tapes
- 22% Fiber volume ratio

2. CVI SiC/SiC

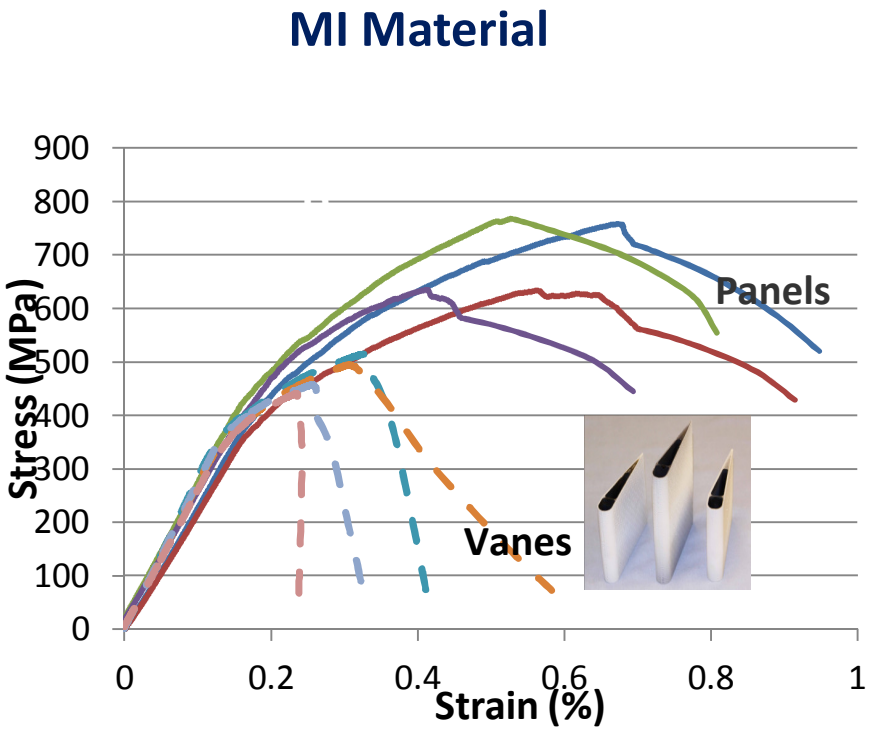
- *Hi-Nic Type S fibers*
- *BN interface coatings*
- 5 HS weave
- 35% fiber volume ratio

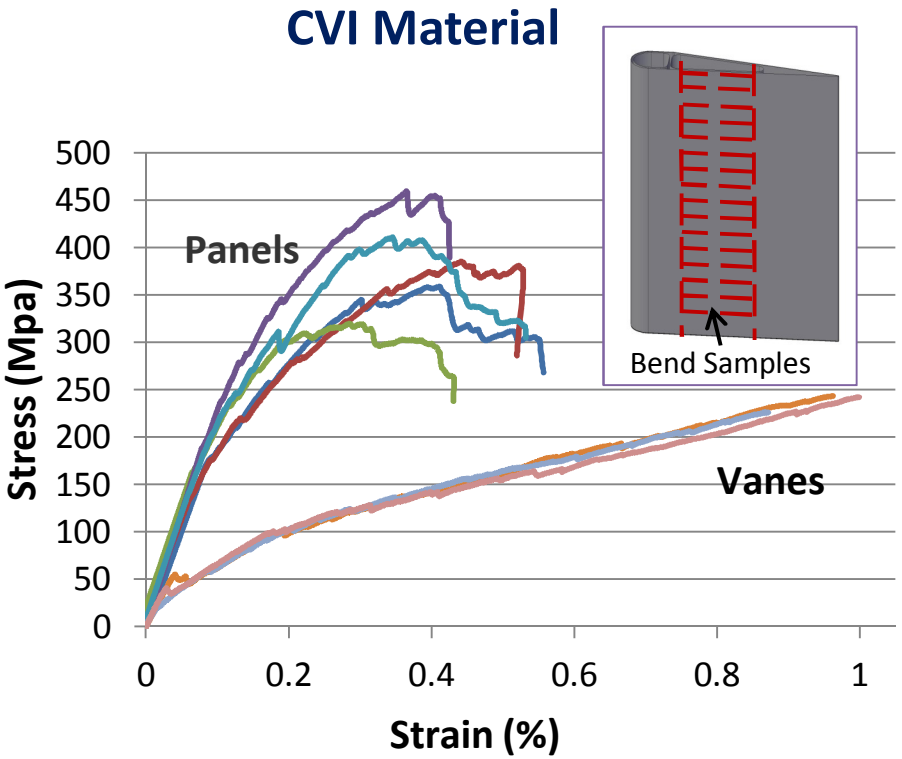
High Pressure Burner Rig simulated turbine operating conditions



30 hours of testing has been completed at 2500ºF, 10 atmospheres and 200 m/s gas velocity

Bend tests showed strength and modulus loss in fabricating vane subelement shapes

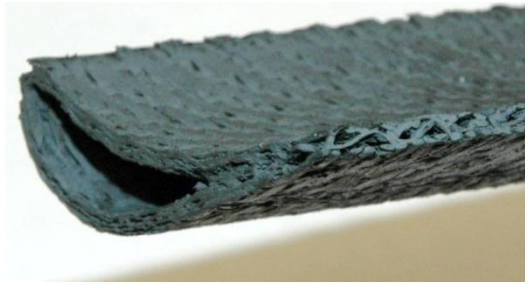




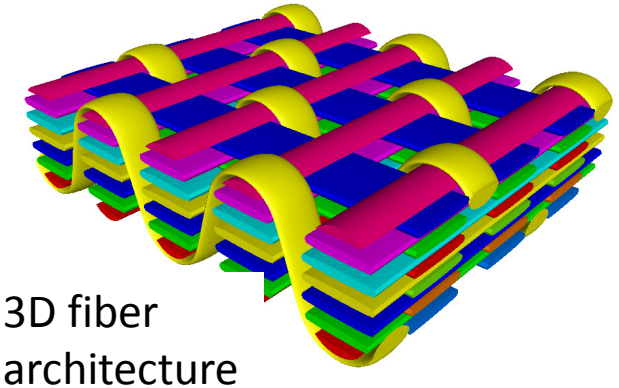
Porosity after infiltration of complex shape reduced strength, stiffness and thermal conductivity of vane subelements

3D CMC concepts for small turbine components

Vane preform



trailing edge cooling holes



3D fiber architecture

blade preform with spanwise cooling holes

Preform : TEAM CVI : Hyper Therm

Innovations:

- Sylramic fiber tows served with rayon fiber for weavability & to minimize fiber damage
- Mo rods (removed after sinter) inserted in preform to form cooling holes

Challenge:

- Retain cooling holes after SiC infiltration

Oxide CMC components for engine noise reduction demonstrated

Quarter-scale exhaust mixer

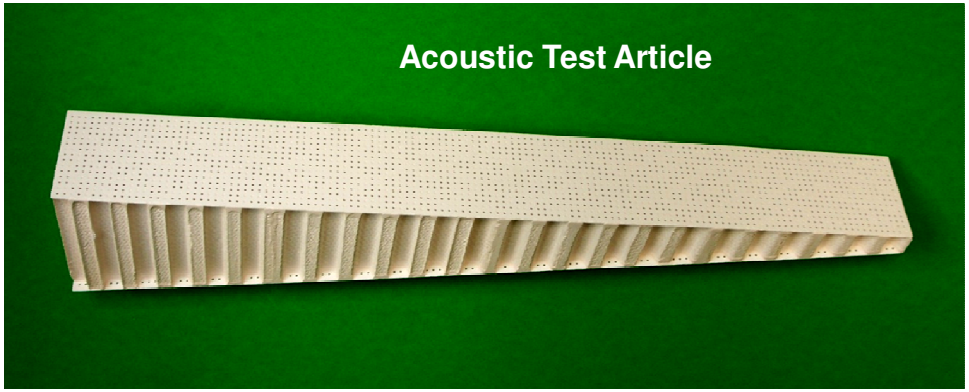
for reduction of engine exhaust noise

- **N610/AS CMC fabricated by ATK/COIC**
- **Aerodynamic and acoustic performance measured at Fluidyne and NASA**
- **Improves durability and reduces weight**
- **Full-scale (AE3007) test article in fabrication**

CMC acoustic liner concept

for reduction of engine core noise

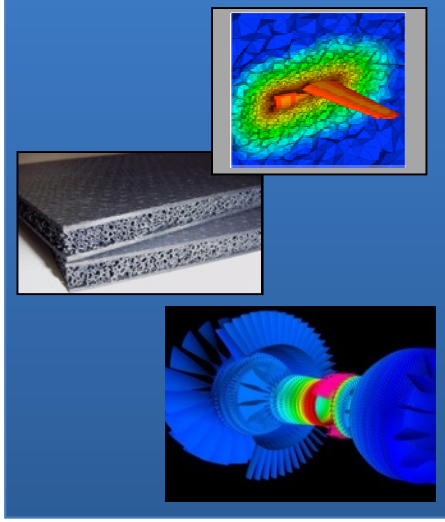
- **N312/AS CMC fabricated by ATK/COIC**
- **For assessment of acoustic attenuation and model validation**
- **CMC construction enables use at higher temperatures near noise source**



Fundamental Aeronautics Projects in 2013

Fundamental Aeronautics Program Office

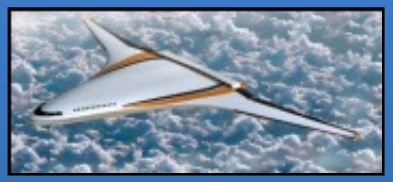
Aeronautical Sciences



Aeronautical Sciences (AS)

Enable efficient design & analysis of aviation systems through physics-based tools & advanced technologies.

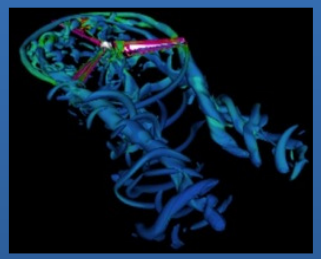
Fixed Wing



Fixed Wing (FW)

Develop technologies for energy efficiency & environmental compatibility

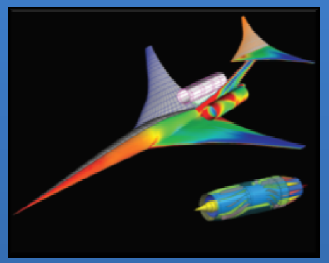
Rotary Wing

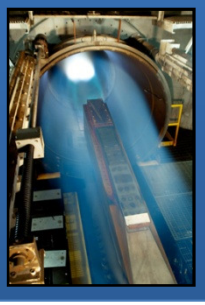


Rotary Wing (RW)

Develop tools & technologies to address key barriers to large rotary wing vehicles

High Speed

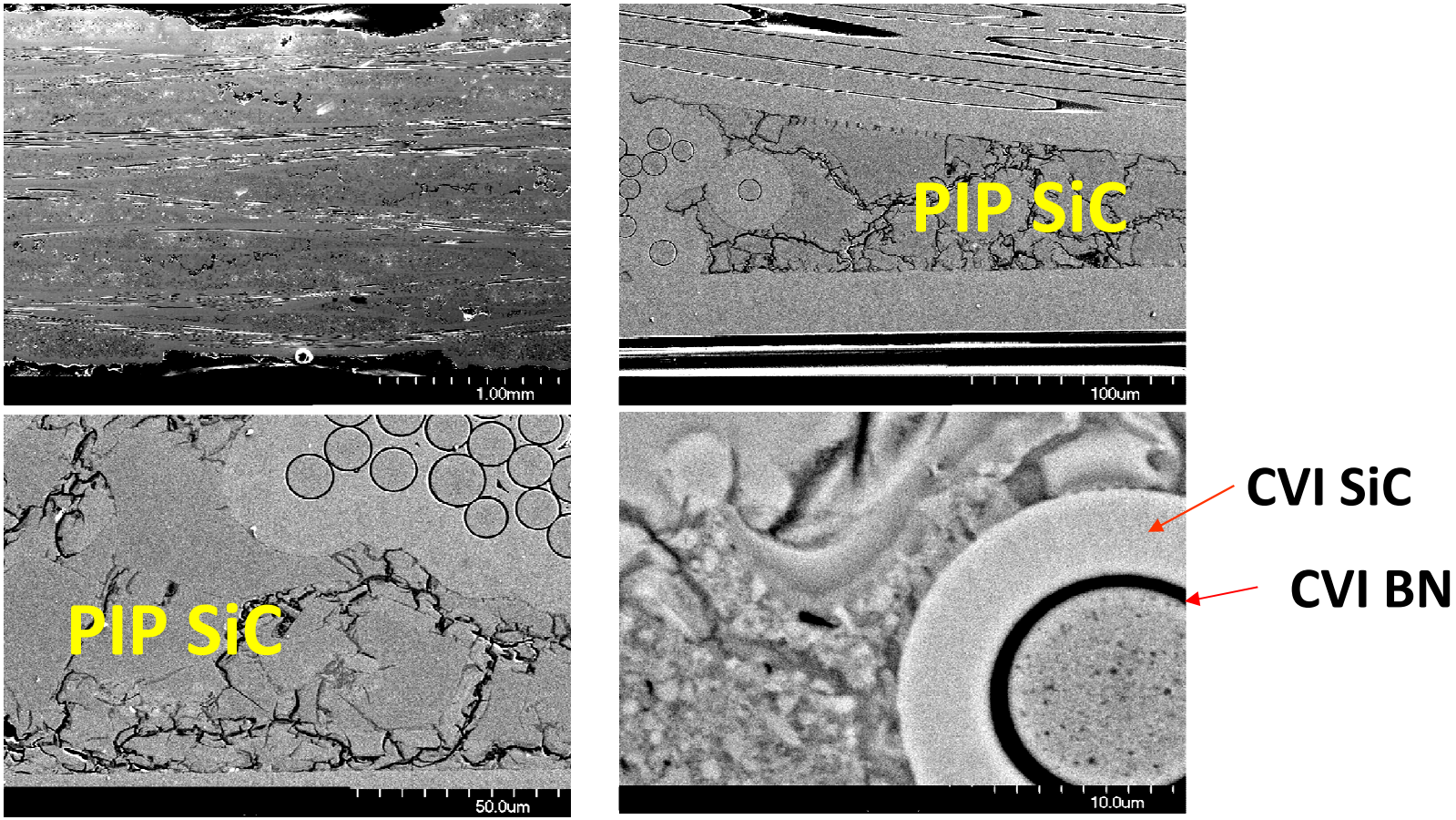




High Speed (HS)

Address environmental & performance barriers to civil supersonic airliners.

Hybrid (CVI + PIP) SiC Matrix



- **Reduced porosity; higher MCS and thermal conductivity**
- **Better oxidation resistance & off-axis properties**

Fabrication Process for 2700°F Fiber

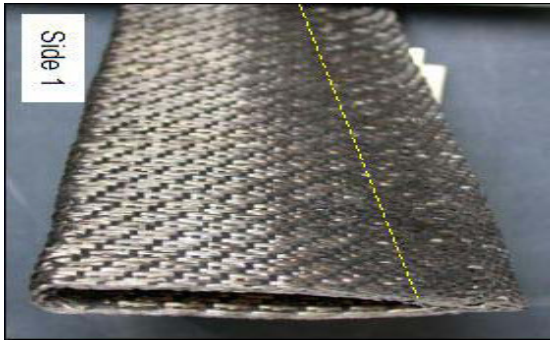
Boron-Sintered SiC Fiber Preform
(formed from commercial "Sylramic" Fiber)

→

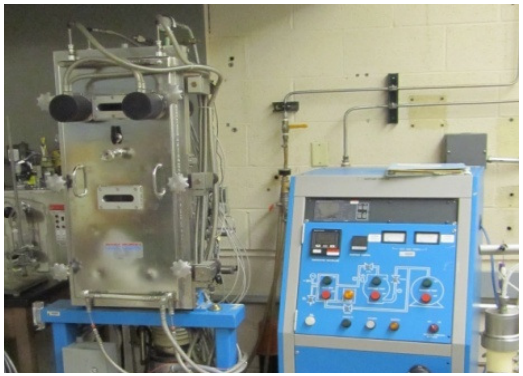
Preform Treatment in High-Pressure N_2
(Boron removal for SOA creep-rupture resistance)

→

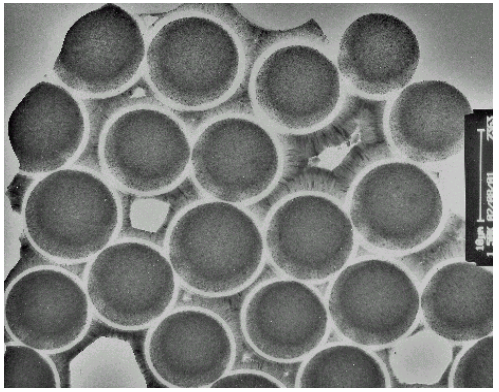
Super Sylramic-iBN Preform
(in-situ grown BN surface layer on each fiber for environmental protection)



Blade Preform



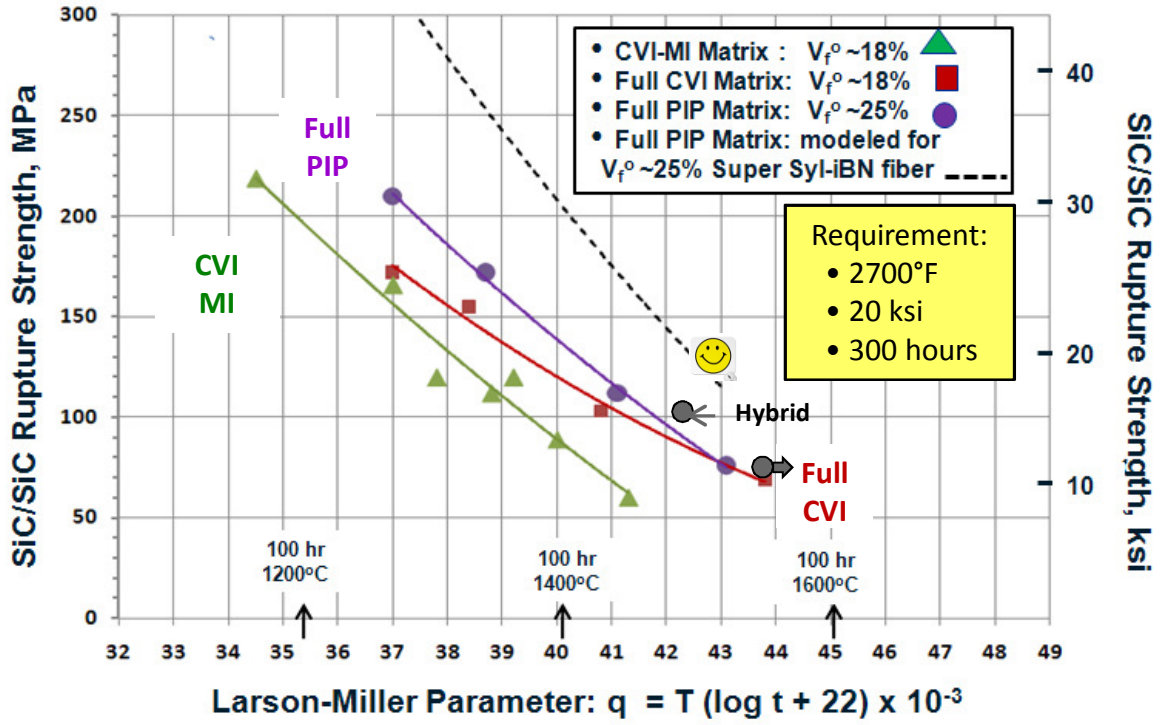
Preform Treatment Furnace



iBN coating between every fiber

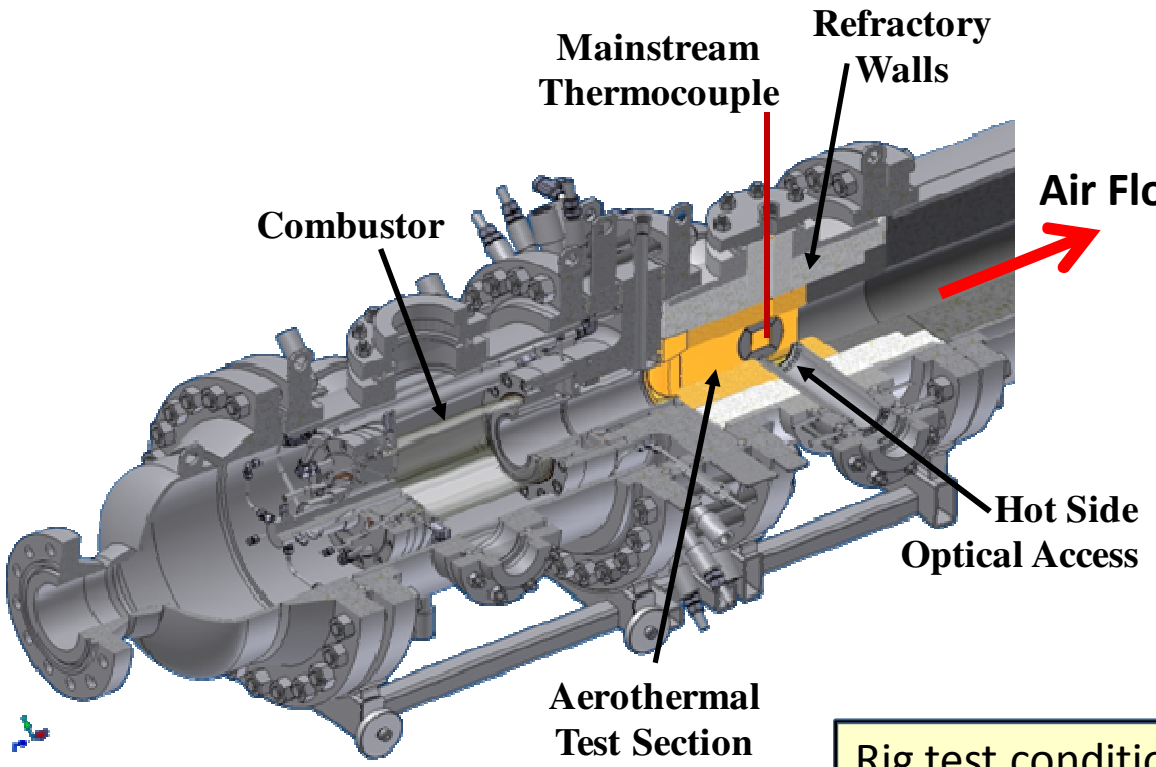
Fiber treatment process improves on 2009 NASA patent for Sylramic-iBN fiber

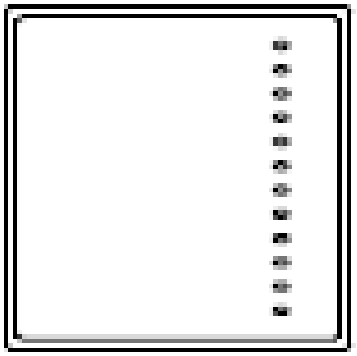
Hybrid Matrix CMC: Durability Comparison



- **Hybrid matrix performs better than PIP due to greater creep-resistance of the annealed CVI SiC component**
- **Hybrid matrix performs better than CVI due to better oxidation resistance of PIP component**
- **Advanced fiber is needed to meet 2700°F turbine goal**

Aerothermal Testing of Cooled CMC Panels





2”x2” CMC test article

- CVI SiC/SiC with BSAS EBC
- 12 cooling holes at 30° slant
- Back side thermocouple

Rig test conditions:

- Gas temperature (2150℉ +)
- up to 325 ft/sec gas velocity
- -1 to 6+ atmospheres pressure
- impingement and film cooling

Testing Planned for July in Aerothermal Rig at National Energy Technology Labs

2013 Plans

- Demonstrate feasibility of alternate fabrication process for 2700°F SiC fiber
- Fabricate hybrid-matrix composites & characterize mechanical properties and durability
- Conduct aerothermal rig testing of cooled CMC panels in collaboration with National Energy Technologies Labs
- Complete 250-hour durability testing and characterization of vane and combustor subelements in engine environment
- Complete fabrication and rig testing of 3D-reinforced vane and blade subelements for small (rotorcraft-size) engines